i) Intracavity sum-frequency mixing: $\omega_1+\omega_2=\omega_3$

1047/1064 nm+(780–1060) nm (SDL-8630)=447–532 nm.

with some tunability.

SDL-8630 tunable laser diode provides 0.5 W output power within 780–1060 nm region with 25 nm tuning range.

j) Intracavity sum-frequency mixing: $\omega_1+\omega_2=\omega_3$

1319 nm (Nd:YAG)+(780–1060) nm (SDL-8630)=490–587.7 nm.

with some tunability.

k) Intracavity difference-frequency mixing: $\omega_1-\omega_2=\omega_3$

(780–1060) nm (SDL-8630)−1319 nm (Nd:YAG)=1.9–5.4 μm.

with some tunability.

l) Intracavity difference frequency conversion between ω_2 (1.75–2.5) μm (Co:MgF) or (1.85–2.15) μm (Tm:YAP) and ω_1, 2.79 μm (Er:YSGG) or 2.94 μm (Er:YAG) or (2.71–2.92) μm (Er:YAP): $\omega_3=\omega_2-\omega_1$ is in the range of 4–10 μm with some tunability.

2. As a supplement for the use of a prism beam expander cavity, the prism expander also acts as a Brewster plate or a polarizer, and naturally become a birefringent filter in conjunction with the KTP.

3. As a supplement for the use of the corner reflector pump head by the following:

(1) It provides one of the best way in the use of diode bars as the side-pumping source for acquiring uniform pumping and for highly concentrating pump power on the center area of the laser rod. In fact, the pumping density and laser gain in the main center area of a laser rod is larger than the rest outside area. This effect is contributed by a) the 4-side pumping, b) the optimizing absorption coefficient and c) the convergent effect of the pumping beams caused by a higher refractive index of a laser rod, and results in a perfect condition in realizing mode-matched pumping, TEM_{00} mode operation, good beam quality and high efficiency.

(2) The direction of polarization of the front and back pump beams is different from that of the top and bottom pump beams. Considering that for some solid-state laser materials, the pump absorptions are strongly depend on the polarization direction, so that the pump polarization needs to be chosen to ensure the strongest pump absorption in such cases. As a solution, four group of diode bars with different optimized polarizations are employed to provide the required polarized pump beams with four equal portions correspondingly, i.e., every single portion's polarization can easily be accommodated for the strongest pump absorption. Thus, this will be much less of a problem in comparison with the difficulty of using single pump beam on pulsed dye lasers as was disclosed in U.S. Pat. No. 5,371,758.

The invention being thus described, it is obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to those skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. In a method for configuring a standing-wave cavity arrangement for solid-state lasers in obtaining stable single-mode operation, whereby overcoming the major difficulty, with intracavity frequency conversions, typically in frequency doubling caused by the so-called "green problem", comprising the steps of

(1) constructing a forming means for said cavity, including at least two end mirrors;

(2) constructing a pump head means placed within said cavity for lasing at a fundamental wavelength;

comprising the steps of

A. selecting a solid-state laser medium means;

B. selecting a pump source means including laser diode bars to provide relevant pumping beams for pumping said laser medium means; and

C. producing a gain region within said laser medium means by said pumping beams;

(3) constructing a formation of wavelength selectivity with low insertion losses placed within said cavity, wherein the performance parameters of said formation are predetermined whereby to sufficiently and uniquely determine the laser's oscillating frequency and to force the laser to perform a stable single-mode or narrow band operation; and

(4) selecting an approach for eliminating or minimizing the spatial hole-burning effect from the group consisting of

A. a first approach, comprising

1) creating said gain region within a narrow area along the optical axis of said cavity and immediately adjacent to one of said end mirrors, and

2) selecting said formation from the group consisting of

a) a first formation comprising a monochromatic polarizer means,

b) a second formation, built up of a Lyot filter and a one-dimensional beam expander means, and

c) a third formation, built up of a spectral filter means including at least one spectral filter, and a two-dimensional beam expander means to reduce insertion losses for said spectral filter means substantially; and

d) a fourth formation comprising an etalon; and

B. a second approach, comprising

1) placing said pump head means between a pair of quarter-wave plates whereby producing the "twisted mode" operation, and

2) building said formation up of a spectral filter means consisting of at least one spectral filter, and a beam expander means to reduce insertion losses for said spectral filter means substantially.

2. In the method of claim 1, wherein said approach is said first approach, further comprising the steps of

(1) using a nonlinear crystal means arranged in an optimal condition including phase-matching for intracavity frequency conversion;

(2) maintaining the bandwidth of said formations to be smaller than the laser longitudinal oscillating mode interval of said cavity, and its free spectral range is larger than the FWHM of lasing bandwidth of the gain medium;

(3) building said monochromatic polarizer means up of a polarizer and said nonlinear crystal means;

(4) selecting said spectral filter from the group consisting of

A. Lyot filters, formed by a polarizing means and a birefringent element; and

B. etalons, including 1) regular etalons, and 2) birefringent etalons which acts likewise as an additional Lyot filter in conjunction with said polarizing means;

(5) selecting said polarizing means from the group consisting of 1) Brewster plate, 2) Brewster surface, and 3) Brewster reflector;

(6) selecting said birefringent element from the group consisting of 1) said nonlinear crystal means, and 2) said birefringent etalon;

(7) selecting said laser cavity from the group consisting of 1) regular standing-wave cavities; 2) V-shaped standing-wave cavities; and 3) L-shaped standing-wave cavities;

(8) building said two-dimensional beam expander means up of an AR coated lens pair; which additionally comprises the steps of

A. placing an aperture means at the focal plane of said object lens where a diffraction-limited point occurs, so that said beam expander means is configured as a spatial filter likewise in conjunction with said aperture means, whereby leading to TEM_{00} mode operation and an output with an excellent spatial quality;

B. keeping a proper defocusing for said beam expander means whereby achieving compensation of the thermal lens effect leading to stable laser operations; and

C. locating said nonlinear crystal means adjacent to said aperture means or within the unexpanded beam portion.

3. In the method of claim 2, wherein said spectral filter means consists of at least one Lyot filter, in order to protect the laser polarization at the fundamental wavelength from being altered or affected by the amount of birefringence of said nonlinear crystal means and said laser medium means; further comprising the steps of

(1) keeping said nonlinear crystal means to have a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength, and

(2) selecting said laser medium from the group consisting of 1) nonbirefringent laser medium, 2) laser medium made and oriented without the exhibition of birefringences, and 3) birefringent laser medium having a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength.

4. In the method of claim 2, further comprising the steps of

(1) maintaining a constant cavity length whereby stabilizing operation frequency;

(2) maintaining a constant temperature for said nonlinear crystal means whereby providing the best result for frequency conversion and minimizing cavity losses for the oscillating mode;

(3) constructing a wavelength tuning form for the alignment of said etalon transmission peak to said laser oscillation frequency; and

(4) constructing a defocusing control means for said two-dimensional beam expander means, wherein the degree of said defocusing is controlled by said control means for different pump and output power levels whereby obtaining good stability against thermal lens fluctuations.

5. In the method of claim 1, wherein said approach is said second approach, further comprising the steps of

(1) using a nonlinear crystal means arranged in an optimal condition including phase-matching for intracavity frequency conversion;

(2) maintaining the bandwidth of said spectral filter means is smaller than the laser longitudinal oscillating mode interval of said cavity, and its free spectral range is larger than the FWHM of lasing bandwidth of the gain medium, whereby to control the residual spatial hole burning;

(3) selecting said spectral filter from the group consisting of

A. Lyot filters, formed by a polarizing means and a birefringent element; and

B. etalons, including 1) regular etalons, 2) said quarter-wave plate, and 3) birefringent etalons, in the later two cases said etalon acts likewise as an additional Lyot filter in conjunction with said polarizing means;

(4) selecting said polarizing means from the group consisting of 1) Brewster plate, 2) Brewster surface, and 3) Brewster reflector;

(5) selecting said birefringent element from the group consisting of 1) said nonlinear crystal means, 2) said pair of quarter-wave plates, and 3) said birefringent etalon;

(6) selecting said laser medium means from the group consisting of 1) nonbirefringent laser medium, 2) laser medium made and oriented without the exhibition of birefringences, and 3) birefringent laser medium having a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength, whereby to protect said "twisted mode" operation from being degraded by the amount of birefringence of said laser medium means;

(7) selecting said laser cavity from the group consisting of 1) regular standing-wave cavities; 2) V-shaped standing-wave cavities; and 3) L-shaped standing-wave cavities;

(8) selecting said beam expander means to be a two-dimensional beam expander means built up of an AR coated lens pair; which additionally comprises the steps of

A. placing an aperture means at the focal plane of said object lens where a diffraction-limited point occurs, so that said beam expander means is configured as a spatial filter likewise in conjunction with said aperture means, whereby leading to TEM_{00} mode operation and an output with an excellent spatial quality;

B. keeping a proper defocusing for said beam expander means whereby achieving compensation of the thermal lens effect leading to stable laser operations; and

C. locating said nonlinear crystal means adjacent to said aperture means or within the unexpanded beam portion.

6. In the method of claim 5, further comprising the steps of

(1) keeping said nonlinear crystal means to have a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength, whereby to protect the polarization and eigenvector of laser operation at the fundamental wavelength from being altered or affected by the amount of birefringence of said nonlinear crystal means;

(2) maintaining a constant cavity length whereby stabilizing operation frequency;

(3) maintaining a constant temperature for said nonlinear crystal means whereby providing the best result for frequency conversion and minimizing cavity losses for the oscillating mode;

(4) constructing a wavelength tuning form for the alignment of said etalon transmission peak to said laser oscillation frequency; and

(5) selecting a defocusing control means for said two-dimensional beam expander means, wherein the degree of said defocusing is controlled by said control means for different pump and output power levels whereby obtaining good stability against thermal lens fluctuations.

7. In the method of claim 1, wherein

(1) said approach is said second approach;

(2) said beam expander means is a prism beam expander which acts inherently as a polarizer likewise and is placed between said pump head means and said nonlinear crystal means, whereby 1) to reduce the insertion losses of intracavity optical elements, particularly for said etalon and said Lyot filter, and 2) to provide both large and small beam waists in one compact cavity, whereby to be able to achieve mode-matched pumping and efficient intracavity frequency conversion at the same time;

(3) said gain region is in the shape of a thin layer whereby accommodating the one-dimensional mode expanding;

and further comprising the steps of

(3) using a nonlinear crystal means located within the unexpanded beamportion and arranged in an optimal condition including phase-matching for intracavity frequency conversion,

(4) maintaining the bandwidth of said spectral filter means is smaller than the laser longitudinal oscillating mode interval, and its free spectral range is larger than the FWHM of lasing bandwidth of the gain medium, whereby to control the residual spatial hole burning;

(5) selecting said spectral filter from the group consisting of

A. Lyot filters, formed by said prism beam expander and a birefringent element; and

B. etalons, including 1) regular etalons; 2) said quarter-wave plate, and 3) birefringent etalons, wherein in the later two cases said etalon acts likewise as an additional Lyot filter in conjunction with said prism beam expander;

(6) selecting said birefringent element from the group consisting of 1) said nonlinear crystal means, 2) said pair of quarter-wave plates, and 3) said birefringent etalon;

(7) selecting said laser medium means from the group consisting of 1) nonbirefringent laser medium, 2) laser medium made and oriented without the exhibition of birefringences, and 3) birefringent laser medium having a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength, whereby to protect said "twisted mode" operation from being degraded by the amount of birefringence of said laser medium means.

8. In the method of claim 7, further comprising the steps of

(1) keeping said nonlinear crystal means to have a constant effective length to produce a phase retardation to be a half integral multiple of said fundamental wavelength, whereby to protect the polarization and eigenvector of laser operation at the fundamental wavelength from being altered or affected by the amount of birefringence of said nonlinear crystal means;

(2) selecting said laser cavity from the group consisting of 1) regular standing-wave cavities; 2) V-shaped standing-wave cavities; and 3) L-shaped standing-wave cavities;

(3) constructing a form for maintaining a constant cavity length for said cavity whereby stabilizing operation frequency, said form includes 1) selecting distance holders for said cavity forming means with a zero thermal expansion coefficient at room temperature, 2) selecting a temperature compensation cavity structure for said cavity forming means, and 3) selecting a temperature control means for maintaining a constant temperature for said cavity;

(4) constructing a temperature control means for said nonlinear crystal means to maintain a constant temperature in the optimal condition whereby providing the best result for frequency conversion and minimizing cavity losses for the oscillating mode; and

(5) constructing a wavelength tuning form for the alignment of said etalon transmission peak to said laser oscillation frequency; said tuning form includes 1) temperature tuning, and 2) angle tuning, in which the rotation axis of said etalon must be perpendicular to the plan expanded by said prism beam expander whereby reducing the etalon walk-off loss.

9. In the method of claim 1, further selecting a nonlinear crystal means arranged in an optimal condition including phase-matching for intracavity frequency conversion, wherein said frequency conversion includes

(1) second harmonic generation, wherein said nonlinear crystal including KTP;

(2) resonantly enhanced second harmonic generation, wherein

A. said nonlinear crystal means including KTP;

B. said spectral filter is said regular etalon; and

C. said cavity arrangement is configured to resonate at said second harmonic frequency by a phase compensator means or cavity distance adjustor means whereby largely enhancing the intensity of said second harmonic radiation and the conversion efficiency;

(3) third harmonic generation, wherein

said nonlinear crystal means is two nonlinear crystals positioned serially, in which the first crystal is set with type I phase-matching for doubling said fundamental radiation to produce the SHG, and the second crystal is set with type II phase-matching to mix said fundamental and second harmonic radiations so as to produce the THG;

(4) third harmonic generation with resonant harmonic generation, wherein

A. said nonlinear crystal means is two nonlinear crystals positioned serially, in which the first crystal is set with type I phase-matching for doubling said fundamental radiation to produce the SHG, and the second crystal is set with type II phase-matching to mix said fundamental and second harmonic radiations so as to produce the THG;

B. said spectral filter is said regular etalon; and

C. said cavity arrangement is configured to resonate at said second harmonic frequency by a phase compensator means or cavity distance adjustor means whereby largely enhancing the intensity of said second harmonic radiation and the conversion efficiency;

(5) fourth harmonic generations, wherein

said nonlinear crystal means is three nonlinear crystals positioned serially, in which the first crystal is set

with type I phase-matching for doubling said fundamental radiation to produce the SHG, the second crystal is set with type II phase-matching to mix said fundamental and second harmonic radiations for producing the THG, and the third crystal is set with type I phase-matching to mix said fundamental and third harmonic radiations so as to produce the FHG;

(6) fourth harmonic generation with resonant harmonic generation, wherein

A. said nonlinear crystal means is two nonlinear crystals positioned serially, in which the first crystal is used for doubling said fundamental radiation to a second harmonic radiation, and the second crystal is for doubling said second harmonic radiation to a quadrupling harmonic radiation;

B. said spectral filter is said regular etalon; and

C. said cavity arrangement is configured to resonate at said second harmonic frequency by a phase compensator means or cavity distance adjustor means whereby largely enhancing the intensity of said second harmonic radiation and the conversion efficiency;

(7) frequency mixing, wherein

A. further selecting an input radiation, including a resonantly enhanced input; and

B. said nonlinear crystal means mixes said fundamental and said input radiations to a mixing radiation; and

(8) frequency mixing with resonant harmonic generation, wherein

A. further selecting an input radiation;

B. said nonlinear crystal means is two nonlinear crystals positioned serially, in which the first crystal is used for doubling said fundamental radiation to produce the SHG, and the second crystal mixes said second harmonic and said input radiations to a mixing radiation;

C. said spectral filter is said regular etalon; and

D. said cavity arrangement is configured to resonate at said second harmonic frequency by a phase compensator means or cavity distance adjustor means whereby largely enhancing the intensity of said second harmonic radiation and the conversion efficiency.

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